ERDC/EL TR-02-30

US Army Corps
of Engineers®
Engineer Research and
Development Center

Aquatic Plant Control Research Program

Advanced Digital Processing of Echo Sounder Signals for Characterization of Very Dense Submersed Aquatic Vegetation

Bruce M. Sabol, Janusz Burczynski, and Joel Hoffman

September 2002

Environmental Laboratory

Approved for public release; distribution is unlimited.

**Aquatic Plant Control
Research Program**

ERDC/EL TR-02-30
September 2002

Advanced Digital Processing of Echo Sounder Signals for Characterization of Very Dense Submersed Aquatic Vegetation

by Bruce M. Sabol

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Janusz Burczynski

Biosonics, Inc.
4027 Leary Way
Seattle, WA 98107

Joel Hoffman

Virginia Institute of Marine Science
P.O. Box 1346
Gloucester Point, VA 23062

Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 33118

Contents

Preface

The work reported herein was conducted jointly by the U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL), Vicksburg, MS, and Biosonics, Inc., Seattle, WA, under the provisions of the Cooperative Research and Development Agreement (CRDA-01-EL-01) between ERDC and Biosonics, Inc. Funding for this work was provided by the Aquatic Plant Control Research Program (APCRP), ERDC, work unit number 33118. The APCRP is sponsored by Headquarters, U.S. Army Corps of Engineers, (HQUSACE), and is assigned to ERDC under purview of the EL. The APCRP is managed under the Center for Aquatic Plant Research and Technology (CAPRT), Dr. John W. Barko, Director. Mr. Robert C. Gunkel, Jr., EL, was Associate Director for the CAPRT. Program Monitor during this study was Mr. Timothy R. Toplisek, HQUSACE.

This paper was originally presented at the Symposium for Acoustics in Fisheries and Aquatic Ecology, Montpellier, France, June 10-14, 2002.

This report was prepared by Mr. Bruce M. Sabol, Environmental Systems Branch (ESB), Ecosystem Evaluation and Engineering Division (EEED), EL, ERDC; Dr. Janusz Burczynski, Biosonics, Inc.; and Mr. Joel Hoffman, Virginia Institute of Marine Science.

This investigation was performed under the general supervision of Dr. Edwin A. Theriot, Director, EL; Dr. David J. Tazik, Chief, EEED; and Mr. Harold W. West, Chief, ESB.

At the time of publication of this report, Director of ERDC was Dr. James R. Houston. Commander and Executive Director was COL. John W. Morris III, EN.

This report should be cited as follows:

Sabol, B. M., Burczynski, J., and Hoffman, J. (2002). "Advanced digital processing of echo sounder signals for characterization of very dense submersed aquatic vegetation," ERDC/EL TR-02-30, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

1 Introduction

Characterizing submersed aquatic vegetation (SAV) is important for a variety of purposes including ecological assessments, impact analyses of human activities, and planning control operations to manage nuisance aquatic plants. Until recently, the standard techniques for characterizing SAV distribution and conditions were by manual means (grab and rake samples, and diver observation and collection) and remote optical techniques (aerial photography and digital satellite image analysis). Manual techniques provided detailed and accurate information, but only for very limited areas. Remote optical techniques provide a large-area synoptic view of SAV distribution but only in limited detail. These techniques are limited by water clarity, commonly underestimating extent of SAV in deeper waters. Recently, an automated digital technique was developed that employs a digital echo sounder, global positioning system, and digital signal processing on a PC in near real time.[1,2] This technique fills the void in methodology by rapidly providing high-resolution information on SAV canopy geometry from a small survey boat.

The boat-based system consists of a digital echo sounder and a real-time differentially corrected global positioning system (GPS) linked to a laptop PC. The hydroacoustic component is a Biosonics DT4000 digital echo sounder (Biosonics, Inc., Seattle, WA,[3] with a 420-kHz, 6-deg, single-beam transducer that generates short (0.1-ms) monotone pulses (pings) at a user-set rate. Return echoes are digitized at high frequency and dynamic range (122 dB). These data are stored on the hard drive of the PC that operates the system. Interspersed with these signal data are GPS position reports (latitude and longitude) recorded at a slower rate (0.5 to 1.0 s^{-1}) from a real-time differentially corrected GPS, using broadcasted corrections.

The system is typically operated by traversing preselected transects in a small survey boat, using GPS navigation guidance. Operating speed is limited to approximately 2.5 m s^{-1} to avoid cavitation around the transducer. Transects are

---

[1] B. M. Sabol, and J. Burczynski. (1998). "Digital echosounder system for characterizing vegetation in shallow water environment," *Proceedings of European conference on underwater acoustics*, A. Alippi and G. B. Canelli, ed., Rome, 165-171.
[2] B. M. Sabol, R. E. Melton, R. Chamberlain, P. Doering, and K. Haunert. (2002). "Evaluation of a digital echo sounder for detection of submersed aquatic vegetation," *Estuaries* 25(1), 133-141.
[3] , W. C. Acker, J. Burczynski, J. Dawson, J. Hedgepeth, and D. Wiggins. (1999). "Digital transducers: A new sonar technology," *Sea Technology* 40, 31-35.

selected perpendicular to the depth contours (if known) or the local shoreline and are roughly parallel to each other at a fixed spacing. Under typical operations (2.5-m s^{-1} boat speed and 5 pings s^{-1}) in 2-m-deep water, a circular bottom area 0.2 m in diameter is sampled every 0.5 m along the transect. While this is less than complete coverage, the speed and/or ping rate may be adjusted to achieve more complete coverage, if desired. High spatial resolution mapping can be performed at around 10 ha hr^{-1}. Higher or lower rates, with associated low and higher spatial resolution, can be achieved by adjusting transect spacing.

The signal for a typical transect containing SAV is illustrated in Figure 1. The transducer provides information on the vertical distribution of echo intensity within the water column. Motion of the survey boat along a linear path yields a two-dimensional (2-D) picture of echo intensity. The bottom usually generates the strongest echo return and is characterized by the sharpest rise in signal echo intensity and typically by very limited change in depth from ping to ping. A flat, unvegetated bottom exhibits a strong return, with a signal "thickness" roughly equal to the pulse width of each ping (pulse duration [0.1 ms] × speed of sound in water [1,500 m s^{-1}] = 0.15 m). At the frequency used, penetration into the bottom is negligible, approximately 2 cm for medium-grained sand.

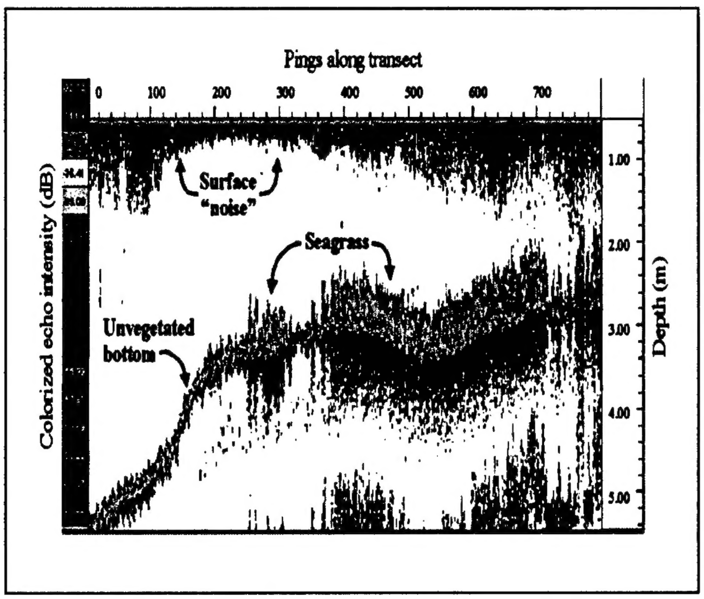


Figure 1. Typical echogram with SAV

Vegetation usually exhibits a contiguous vertical echo return immediately above the bottom that is weaker than the bottom return but stronger than ambient water column "noise." The depth of the top of the vegetation canopy is much more variable, from ping to ping, than that of the bottom, because of patchiness of vegetation and local variability in canopy height. A signal mirroring the vegetation appears below the bottom, presumably the result of reverberation (multiple scattering) of the signal within the vegetation. When vegetation or large-scale bottom roughness occurs, the signal around the bottom appears to grow thicker, indicating a wider range of time for which echoes are returning. The signal processing algorithm utilizes these features to detect and track the bottom, and then to detect and characterize vegetation.

The bottom depth for a local region (~2 to 3) is estimated by determining the mode of the depth of the primary peak in echo intensity within the pings situated between sequential GPS reports. Once the bottom is determined, the algorithm searches upward from the detected bottom for plant-like features. These features include a contiguous echo return exceeding a user-set threshold and found below a "quiet zone" attributed to open water. The height of this feature closely matches in situ plant canopy height. This heuristic algorithm proceeds through a set of tests to sequentially classify each ping into one of the following classes: NOISY, OUT_OF_WATER, TOO_DEEP, UNCLASSIFIED, BARE, and PLANT. The first four classes represent pings rejected for data quality reasons or unvegetated pings. The last two classes are arrived at by processing remaining UNCLASSIFIED pings through a series of tests to definitively identify unvegetated or vegetated conditions. The processor outputs depth, plant height, and plant coverage at the GPS data rate. Plant height is the average plant height of PLANT pings within a reporting cycle and plant coverage is the portion of PLANT pings within a reporting cycle. The logic within this algorithm is hardcoded, although the user may set the intensity and depth thresholds to optimize for site-specific conditions.

Initial development and testing of the algorithm was performed in a southwest Florida estuary system containing bladed grass species of SAV and a hard sandy bottom. The technology for the patented processor, originally developed by the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, has been licensed to Biosonics, Inc., which markets the hardware and processor as EcoSAV version 1.0. Since initial development, the system has been used in a wide variety of locations with varying conditions and SAV species. It has worked well under many conditions common to SAV-colonized areas.[1,2]

SAV detection performance begins to deteriorate when conditions severely depart from the original testing site and the inherent assumptions within the logic. Problems may result from inappropriate selection of processing parameters, occurrence of conditions that violate one or more of the inherent assumptions of the processor, or insufficient information content within the signal to extract the desired attributes. Observed problem conditions are listed in Table 1, along with probable causes for the problem within the algorithm, the impact on the data, and possible approaches to correct the problem.

For any deficiency in meeting a processing objective, it must be determined whether there is sufficient information content in the signal to extract the desired information or, if not, to determine what type of sensor is required to generate a signal containing the extractable information. Obviously, it is desirable to extract as much information as possible from an existing sensor before investing in new sensors. Several approaches have been contemplated for resolving these

---

[1] B. Sabol and J. Burczynski, 1998, op. cit.

[2] B Sabol, R. E. Melton, R. Chamberlain, P. Doering, and K. Haunert, 2002, op. cit.

Table 1
Conditions Resulting in Poor Detection and Characterization Performance

Condition			Current Algorithm Response	Impact on Data	Cause of Problem	Suggested Potential Solutions
Description		Examples				
1	Rapidly changing bottom depth in localized area	Boulder bottom, edge of dredged channel	Inability to correctly track bottom	Missed and false plant detects, incorrect plant height estimates	Violates assumption of slowly changing bottom depth	Slower survey boat speed, faster ping rate, or different algorithm for bottom tracking
2	Nonplant objects on bottom that resemble plants	Stumps, sticks, branches, or debris in potential plant growth areas	Objects declared to be plants	False plant detections	Objects meet requirements for plant detection	Using split-beam transducer to detect coherent returns
3	Low bottom reflectivity	Unconsolidated clay and mud bottoms	Bottom may be declared to contain plants	False plant detects	Sharpest rise feature may not be the bottom	Adjust processing parameters for "thick" bottom
4	Nonbuoyant plants	*Chara* sp., *Nitella* sp., *Ceratophyllum demersum*	Plants not detected	Missed plant detections	Sharpest rise feature not the bottom	Adjust processing parameters for correct bottom thickness
5	Low-density plants	Short overwintering stands of *Vallisneria* sp., *Halodule* sp.	Plants not detected	Missed plant detections	Insufficient signal, plants too short	Use higher-frequency transducer
6	Bottom tracking lost through very dense plant canopy	Dense *Myriophyllum spicatum* or *Hydrilla verticillata* canopies	Incorrect detected bottom depth	Incorrect depth, plant height and coverage	Bottom totally obscurred by dense canopy	Use lower or multiple-frequency transducers
7	Vegetation signal not contiguous with bottom		Canopy tops rejected as vegetation	Missed plant detections	Algorithm assumes contiguous signal from bottom to top of plants	Different processing logic in algorithm
8	Vegetation reaching surface	Any species of plant reaching surface	Signal rejected as "Noisy"	Missed plant detections	Topped vegetation resembles water column noise	Postprocessing editing

limitations (Table 1). These include developing different processing approaches using different or multifrequency transducers and split-beam transducers. To improve performance of the processor and make it more effective under a wider range of conditions, we will examine each condition in light of these alternatives to determining the best approach for enhancing the system's performance.

This report examines the dense canopy problem (conditions 6 and 7 in Table 1) by using multifrequency acoustical data from a dense *Myriophyllum spicatum* (milfoil) site collected over the course of a growing season. Processor outputs over the growing season are examined and the signals associated with successful and unsuccessful processing are characterized. In particular, the results of using a lower-frequency transducer in addition to the frequency customarily used are examined, with the expectation that the lower frequency would be less sensitive to the vegetation and thereby have better ability to penetrate the vegetated canopy and correctly track the bottom. Specific recommendations are offered for means to improving processing under the dense canopy condition. Finally, a concept for a configurable logic software processor is described in which the user would define the logical tests performed in addition to defining the features and threshold levels used, thereby enabling greater flexibility in tailoring the processor to specific site conditions.

2 Methods

Site Description

A site seasonally colonized by extremely dense patches of milfoil was chosen near the Montlake Cut (Seattle, WA), a boating channel that connects Lake Washington to the Puget Sound. At this site, a fixed transect was selected that included a shallow beach with sparse milfoil, a deep channel lacking vegetation, and a shallow flat where milfoil canopies had been observed to reach the surface during late summer. Sampling for species composition and regions of dense plant colonization was completed during the previous summer,[1] when plants could be easily observed from the surface.

Sampling was completed with a 128-kHz, 6-deg, single-beam BioSonics DE transducer, a 418-kHz, 6-deg, single-beam BioSonics DE transducer, and a JRC 2000 differential GPS. The transducers were deployed at the surface on a pole-mount attached to the research vessel. The transducers were not operated simultaneously; one pass of the transect was completed with each transducer. Both transducers were set to operate at 5 pings s^{-1} with a pulse-width of 0.1 msec and threshold of −130 dB, verified settings.[2]

The transect was sampled on four different dates throughout the growing season, representing late winter growth (27 Mar 2001), early growth (15 Jun 2001), midsummer growth (13 July 2001), and peak summer growth (16 Aug 2001). On-board navigation was completed using a commercial navigational software package. Transects were not perfectly replicated because of weather conditions and presence of recreational boaters; at most transects differed by 15 m. In the analysis, we did not assume that the exact same plant locations were sampled on repeated surveys, and we therefore did not attempt any one-to-one matching between surveys. Rather, regions within the transect were considered to represent the same general location, which probably has similar plant conditions.

[1] J. Burczynski and J. Hoffman, unpublished data.
[2] B. Sabol, R. E. Melton, R. Chamberlain, P. Doering, and R. Haunert. 2002, op. cit.

Analyses

The path of each transect was plotted and clipping points were selected to form a common beginning and ending point for all transects. Echograms of the clipped transects were plotted using common scales and colorization to visualize the signal. Parameters for signal processing were selected by iteratively processing the data to achieve maximum detection rates in all areas except the unvegetated channel (a list of specific parameters used in this processing may be obtained from the first author). The focus of this analysis is on bottom detection, which is the prerequisite for correct vegetation detection and characterization. Plots of the detected bottom were generated for each transducer and survey to detect successful versus unsuccessful processing. The echo intensity of adjoining pings in an area subject to late summer processor failure are plotted and compared with those from the same location taken earlier in the growing season during which the processing was successful. Finally, output vegetation height and bottom depth within this region were also plotted to identify specific modes of processor failure.

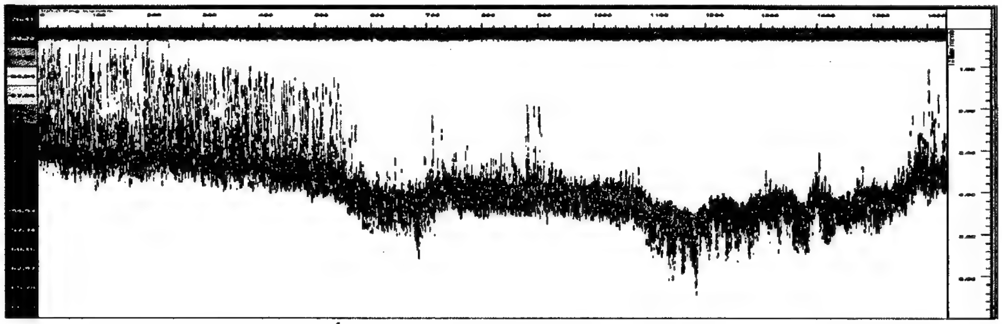
3 Results

The echograms (Figure 2) representing the 2-D distribution of echo intensity indicate that similar plant regions were sampled in repeated surveys. Note that echograms for the 128- and 428-KHz transducers represent horizontal mirror images of each other since they were run in opposite directions (128 KHz south to north; 428 KHz north to south). Similar bathymetric conditions are evident between transducer and sampling month, indicating no great depth differences between repeated transects.

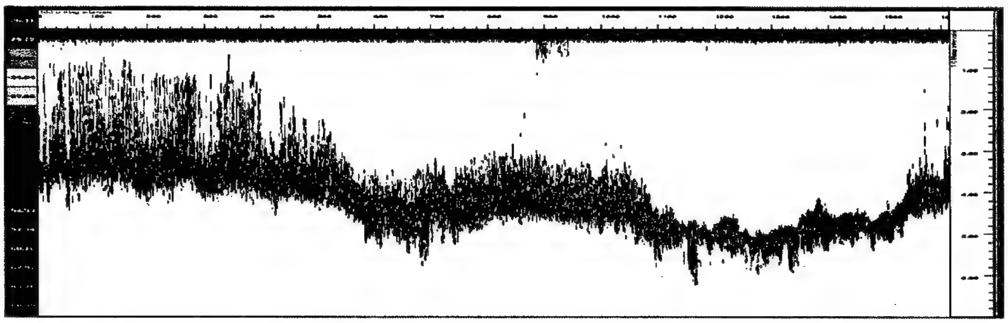
Canopy development is evident through the growing season (Figure 2). In March, the milfoil is already quite tall toward the south end of the transect; in other areas, it is evident but relatively short. For subsequent samplings in May and July, the milfoil gets taller and apparently increases in density. Only the dredged channel area consistently shows little to no plant growth. The August survey shows a considerably different condition. The canopy has reached maximum height and the bottom is not evident in many locations, particularly with the 128-KHz transducer. Unlike earlier months, echo intensity between the canopy top and the bottom has decreased.

The detected bottom depth for a 280-m segment of the transect is illustrated (Figure 3). This segment is run in a northerly or southerly direction so that depth is plotted against latitude. Slight global depth adjustments were made to achieve a better match because of slight variations in water level and depth of transducer mounting from survey to survey. Detected depths are in close agreement for March and May surveys for both transducers. In July, the detected bottom is occasionally more shallow in areas of dense vegetation. By August, the detected depth is much more shallow for vegetated areas, particularly for the 128-KHz transducer.

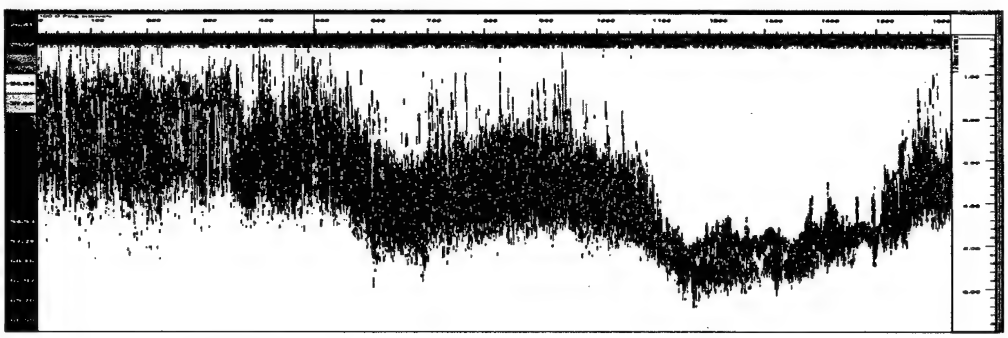
Within a region of failed bottom detects in the August survey (around latitude 47.64466 deg N), the echo intensities for four adjoining pings are plotted (Figure 4) for both frequencies and March and August surveys. There is not a one-to-one correspondence between pings from each survey, but they should be representative of the same approximate location. At this location both transducers successfully detected the bottom (around 3 m) in the March survey but failed in the August survey (Figure 3). While even March vegetation was dense, the bottom most often generated the largest echo returns (typically around -47 dB for the 128-KHz transducer and around -40 dB for the 428-KHz transducer). By August, the canopy top consistently generates the largest echo intensity. A minor peak corresponding to the bottom is evident in the August data, but it is typically



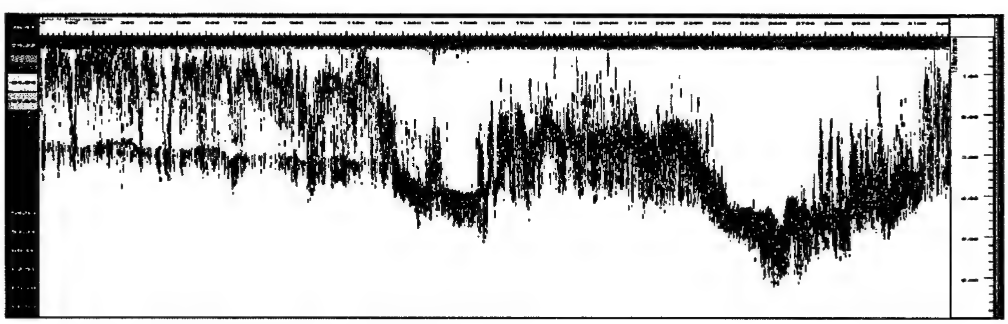
a. March survey, 128-KHz transducer



b. May survey, 128-KHz transducer

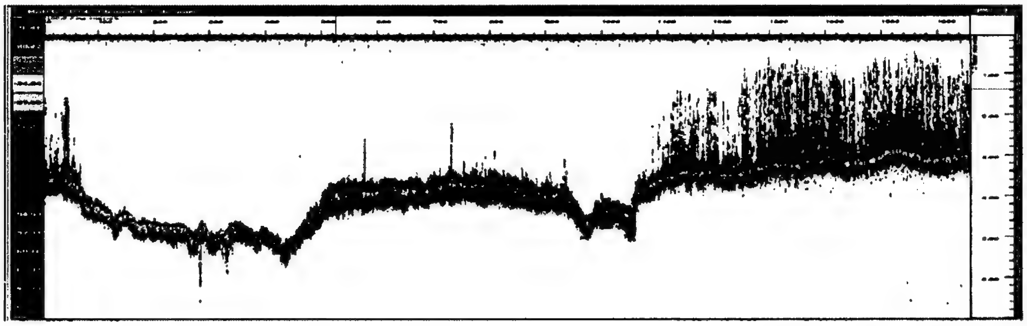


c. July survey, 128-KHz transducer

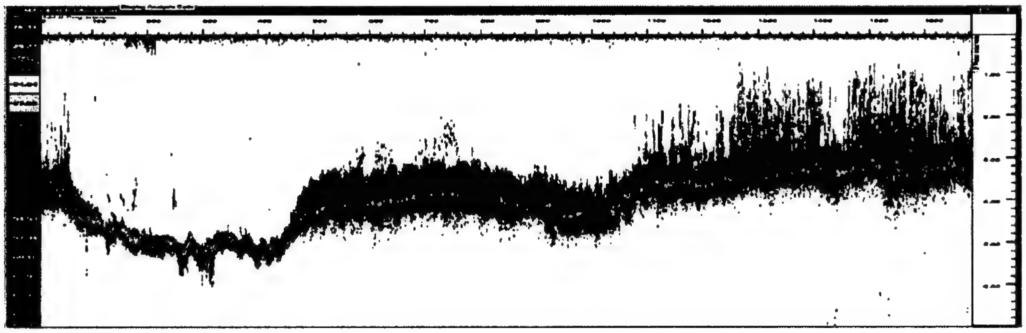


d. August survey, 128-KHz transducer

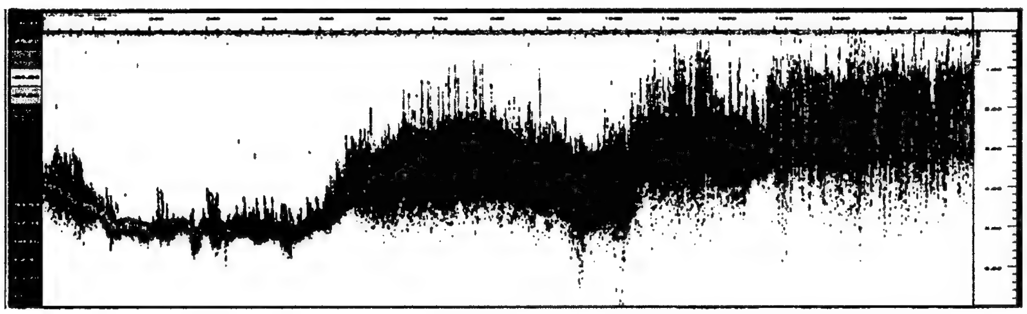
Figure 2. Echograms for each sampling month and transducer used



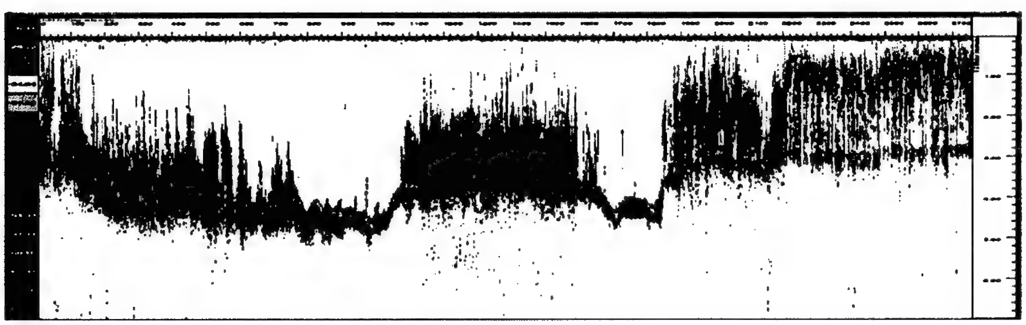
e. March survey, 428-KHz transducer



f. May survey, 428-KHz transducer

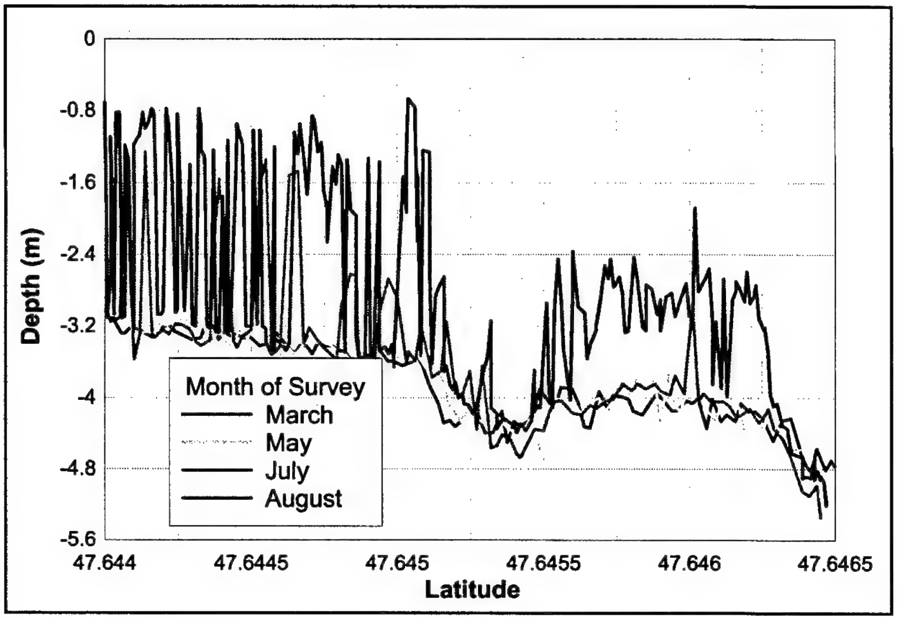


g. July survey, 428-KHz transducer

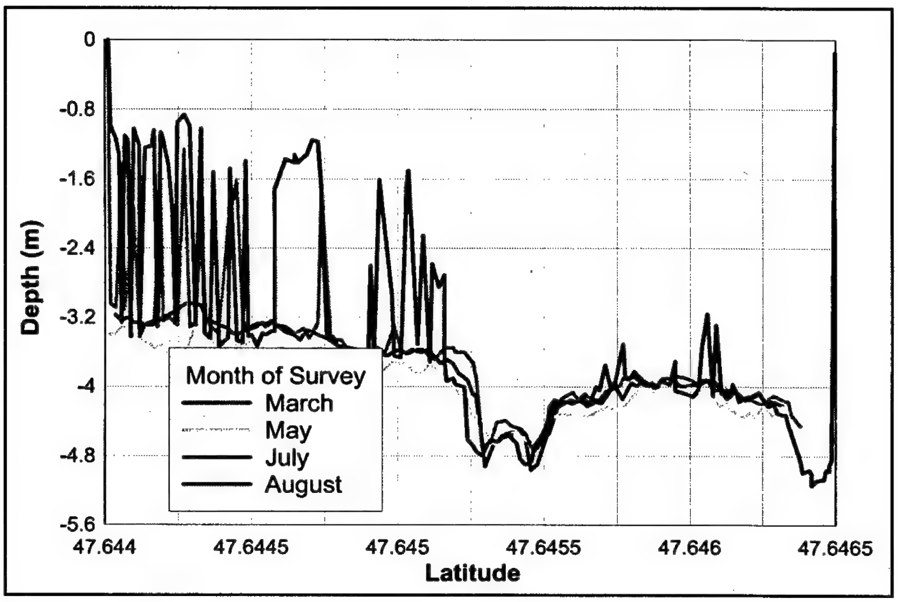


h. August survey, 428-KHz transducer

Figure 2. (Concluded)

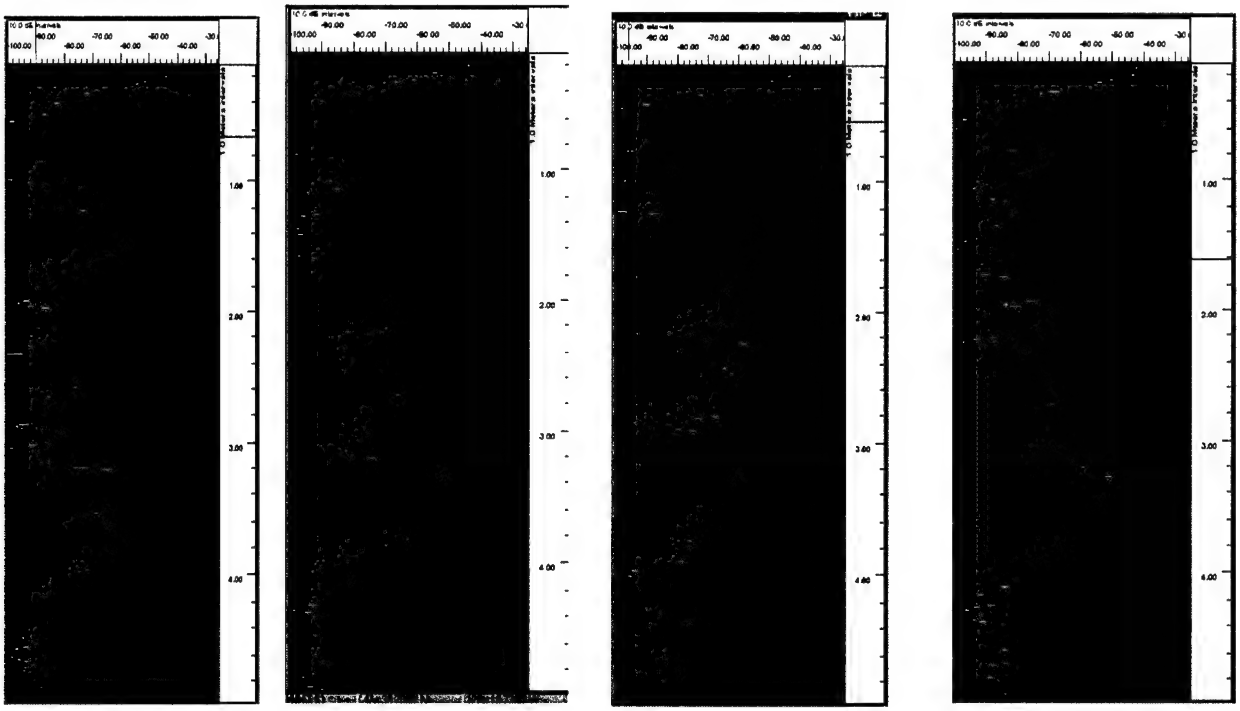


a. 128-KHz transducer

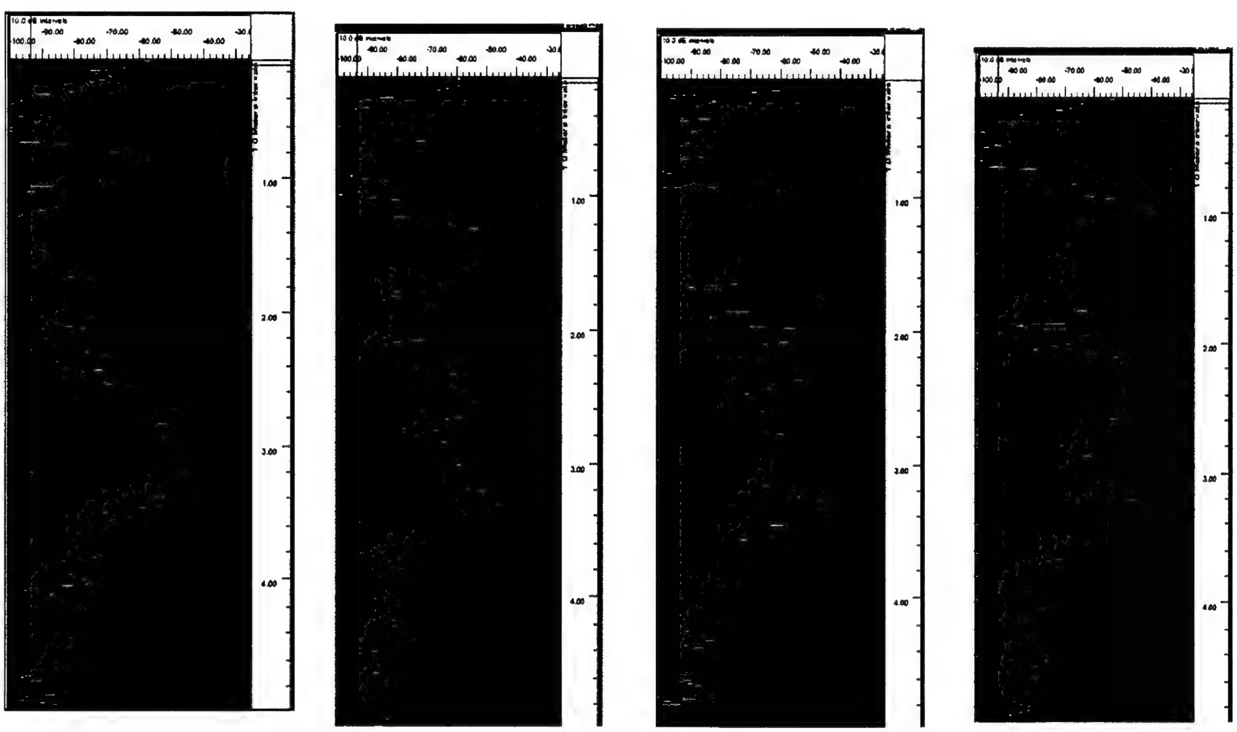


b. 428-KHz transducer

Figure 3. Detected bottom depth by month and transducers

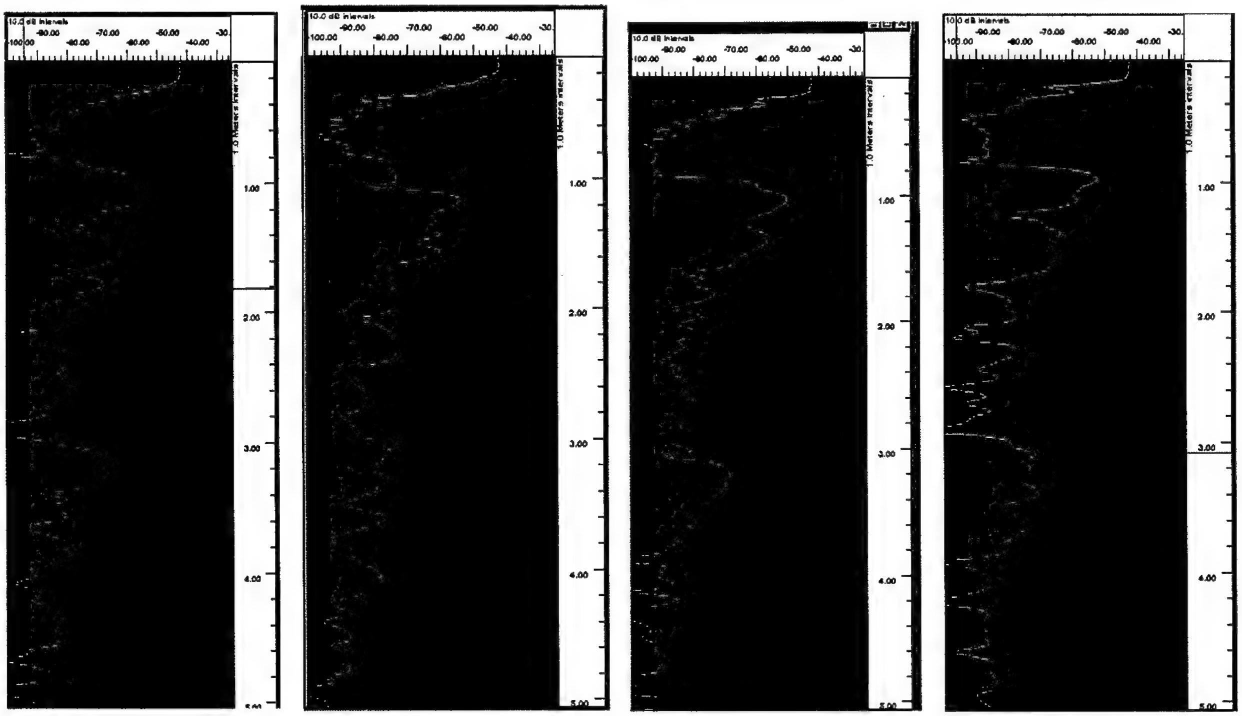


a. March survey 128-KHz transducer; depth approximately 3.3 m

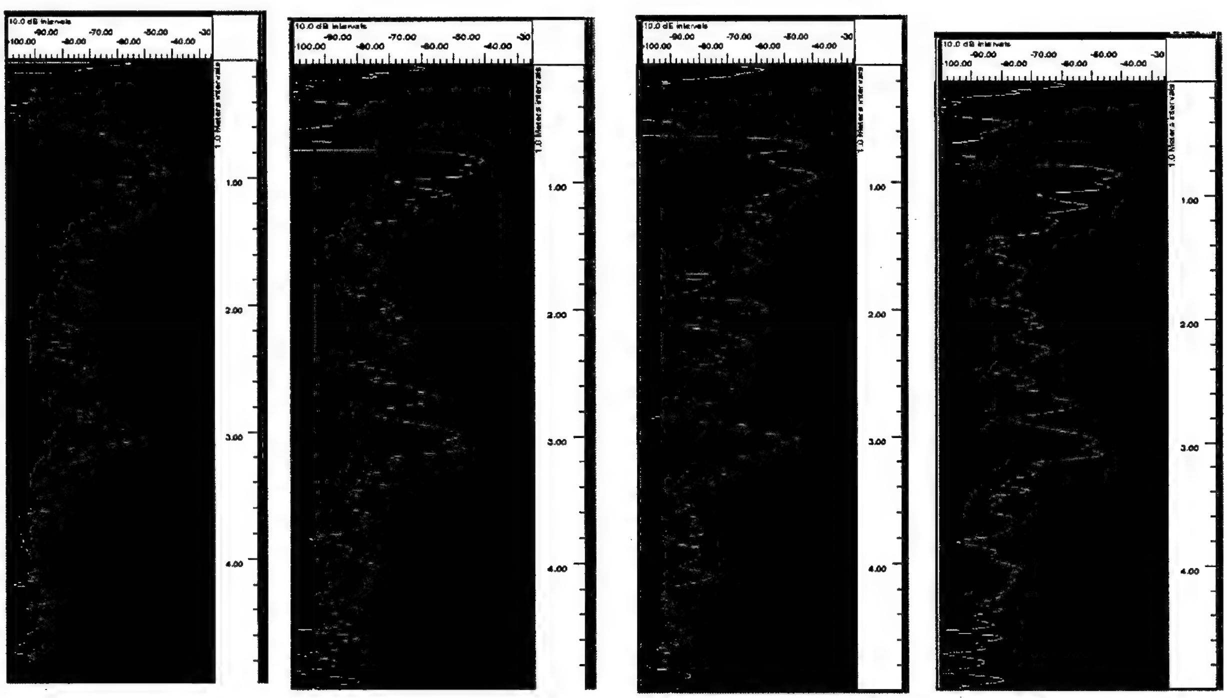


b. March survey, 428-KHz transducer; depth approximately 3.2 m.

Figure 4. Oscilloscope view of four adjoining pings in region of dense milfoil



c. August survey, 128-KHz transducer; depth approximately 3.2 m

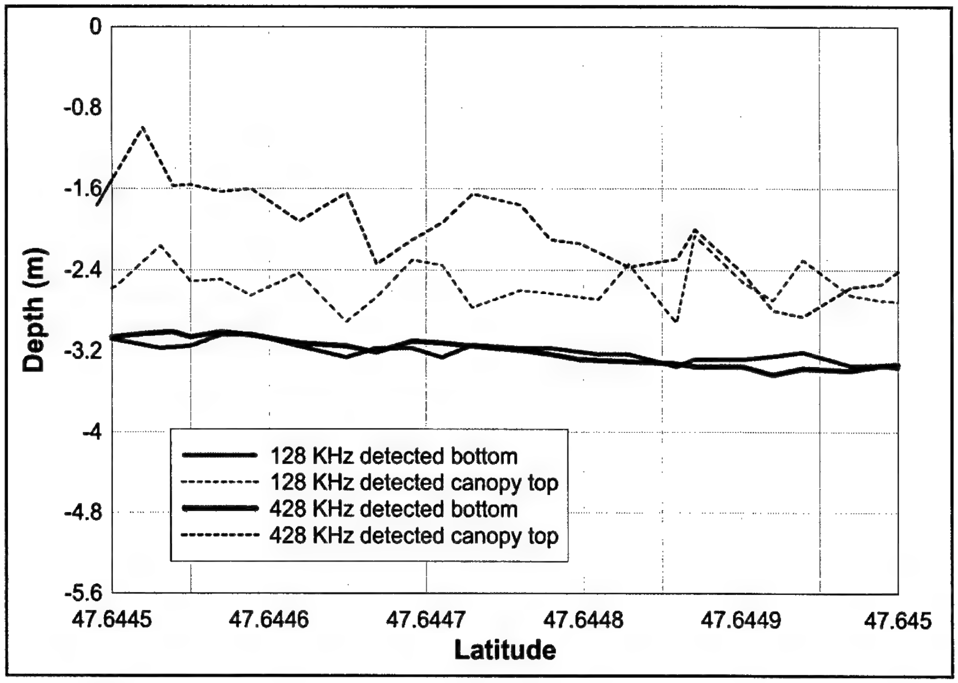


d. August survey, 428-KHz transducer; depth approximately 3.0m

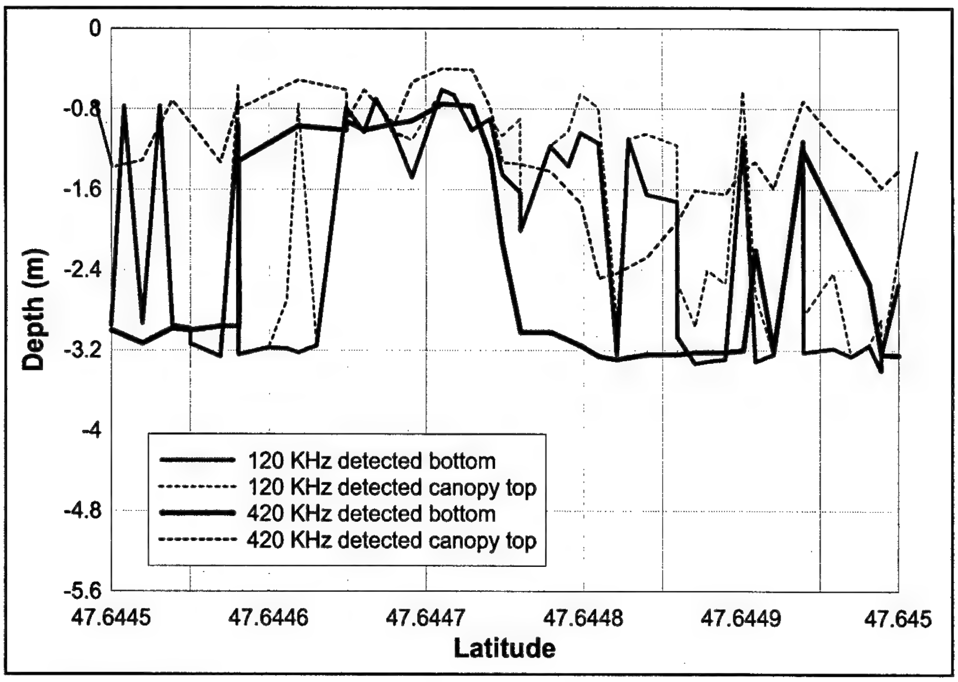
Figure 4. (Concluded)

around 10 dB below that of the canopy top. For the 428-KHz transducer, this bottom peak is typically the second largest peak after the canopy top. For the 128-KHz transducer, the bottom peak is less obvious, frequently being the third or fourth largest peak after canopy top.

Processor outputs within this problematic region, including detected depth and top of canopy, are illustrated for the March and August surveys (Figure 5). The processor generated reasonable values for the March survey, based on comparison with the corresponding echograms (Figure 2). Outputs for the August survey show two modes of processor failure. The first type is failure to correctly detect the true bottom depth (approximately 3.0 to 3.3 m). This subsequently results in artificially low estimates of plant height and coverage because the algorithm looks upward from the "detected" bottom (actually canopy top) and finds little additional vegetation. A second mode of failure is evident when the bottom depth is correctly detected, but no vegetation is detected in spite of obvious vegetation within the echogram at that location (Figure 2). This is specifically evident for the 128-KHz transducer at location 47.64455 deg in August.



a. March survey



b. August survey

Figure 5. Processor detected bottom depth and canopy height within dense milfoil area

4 Discussion

Plants exhibited rapid vertical growth during the first half of the growing season. Strong contiguous echo signals were evident from the top of the plants to the bottom, indicating a fairly uniform distribution of scatterers over the length of the stem. The bottom was still the strongest acoustic target during this part of the season. Later in the season, a highly reflective canopy developed at the top of the fully elongated stems and echo intensity below the canopy diminished significantly. This would be caused either by a reduction of biomass density below the fully developed canopy or by reduced acoustic energy penetrating the canopy to measure scatterers below. Frequently the bottom was not acoustically "visible" below the dense canopy. These observations are in general agreement with morphological descriptions of milfoil growth and canopy formation over the course of a growth season.[1]

Early in the season, the processing algorithm appeared to perform well. Bottom depths were consistent and reasonable, and vegetation showed a steady increase in height and density. As the canopy formed later in the season, the bottom tracking function progressively failed, resulting in subsequent failure to correctly detect and characterize vegetation. Additionally, decreased signal from plant material below the canopy, possibly the result of sloughing of leaf material below the canopy,[1] frequently resulted in no detection of plants even when the true bottom was successfully detected.

The authors originally hypothesized that the lower-frequency transducer (128-KHz) would have better canopy penetration ability and would exhibit better bottom tracking performance. This was clearly not the case. Between the two, the higher-frequency transducer (428-KHz) exhibited a more distinct bottom signal under dense canopy conditions and, consequently, better bottom detection performance. This appears counterintuitive, since the lower frequency is less sensitive to small objects (scattering by plant material). Either way, we conclude that lower frequency is not the direction to improved performance. A sensor option not tested as part of this study is the use of a 428-KHz transducer with a narrower beam width. It may be possible for a narrower beam to more easily find gaps in the canopy and thus detect the bottom with greater regularity.

[1] J. W. Barko and R. M. Smart. (1981). "Comparative influences of light and temperature on the growth and metabolism of selected submersed freshwater macrophytes," *Ecological Monographs* 51(2), 219-235.

The modes of failure point to directions for seeking performance improvement. Of the two, the second is most easily addressed. Here the processor fails to detect vegetation represented by a canopy reflectance but no contiguous echo signal above the selected threshold between the canopy and the correctly detected bottom. The oscilloscope graphic (Figure 4) reveals that there is in fact a contiguous signal, around -80 to -75 dB, depending on the frequency, below the canopy top, which is typically greater than that from the open water "quiet zone." The solution is simply to lower the noise and plant detection threshold to that level (-70 dB and -65 dB were originally used for processing the 128-KHz and 428-KHz signals, respectively). This problem originated from the assumption that there must be a contiguous signal between the top and bottom of the plants to generate a detection. This requirement serves to reject suspended and swimming objects (fish) within the water column, and it works well for grass-like SAV, which exhibit more uniform biomass distribution over the height of the plants.

The first mode of failure is more problematic. Correct bottom tracking fails because the bottom is obscured by vegetation and represents only a minor peak within the signal. Several algorithm improvements may be possible. Since the bottom is still evident below the canopy (Figure 4) as a secondary or tertiary peak, it may be possible to histogram the depth of multiple peaks, weighting each by its ranking within the return signal, or by its distance to the previously estimated bottom depth. Another modification would be easier to implement but would have an operational requirement in the manner surveys are performed. The depth of the first object encountered above a set intensity threshold is easily detected and is typically the top of the SAV canopy. Multitemporal surveys of a fixed transect, designated by GPS waypoints, could be performed. Bottom depths could accurately be determined based on processor output from surveys during periods of low vegetation. These could be combined with later surveys to estimate plant height, giving careful attention to transect navigation, changes in water level, and transducer mounting depth.

These modifications and others yet to be identified would require basic coding changes to the current algorithm. This is a costly operation requiring time to make the modifications and time to verify and validate the changes with testing. It would be far superior to define specific logic tests required within the algorithm using an input configuration file. This has given rise to the concept of a configurable logic processor. Currently, we use a configuration file to specify all intensity and depth/distance thresholds within the algorithm, although the logical tests are hardcoded. Configurable logic would allow the user to:

a. Identify channels to be used within a multifrequency, multiplexed signal.

b. Define the specific features to be extracted and used.

c. Specify filters and processors to be run on these features, such as the modal filter currently used for bottom tracking.

d. Specify the sequence of logical tests performed to detect and quantify attributes of the shallow water environment.

e. Specify outputs and formats, and final postprocessing data quality checks.

Such a capability would end the need for recoding to achieve specific detection objectives and would serve a very flexible research tool. This capability would have two components. The first would be the configurable logic processing engine. The second would be a library of configuration files that could be used to achieve specific processing objectives. EcoSAV 1.0 would be one configuration file representing a good general-purpose processor. Specialized conditions, such as dense canopy-forming SAV, rocky bottoms, low-density SAV, etc. would each be represented in a specialized configuration file developed for processing these conditions. Biosonics, Inc., is currently developing the configurable logic processing engine. Biosonics and their associated user community are developing specifications for the various specialized configuration files.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
September 2002

2. REPORT TYPE
Final report

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Advanced Digital Processing of Echo Sounder Signals for Characterization of Very Dense Submersed Aquatic Vegetation

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Bruce M. Sabol, Janusz Burczynski, Joel Hoffman

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
33118

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
See reverse.

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/EL TR-02-30

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
An algorithm has been developed and previously described for detecting and characterizing submersed aquatic vegetation using the digital signal of a vertically oriented, single-beam, single-frequency echo sounder. It has performed well under most conditions for characterization of submersed vegetation in shallow fresh and estuarine waters. Several types of conditions have proven to be problematic. These include detection of extreme low-density vegetation (<60g (wet)/m^2), accurate detection of vegetation in areas of rocky substrate, and correct bottom tracking and vegetation characterization under extremely dense canopy conditions. Using a multitemporal dataset, we examine current processing problems for a dense canopy condition and develop alternative processing approaches to improve system performance. A strategy for a configurable logic signal processor software system is described which would enable specialized processing to be performed without the need to rewrite digital signal processing code.

15. SUBJECT TERMS
Detection
Digital signal processing
Echo sounder
Submersed aquatic vegetation

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED		23	

7. (Concluded).

U.S. Army Engineer Research and Development Center
Environmental Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39180-6199;
Biosonics, Inc.
4027 Leary Way
Seattle, WA 98107;
Virginia Institute of Marine Science
P.O. Box 1346
Gloucester Point, VA 23062